WASH-

NP-12-9

Draft V

FINAL REPORT

RADIOLOGICAL SURVEY OF THE SIMONDS SAW & STEEL COMPANY

R. W. Leggett, J. Burden, M. T. Ryan,
D. L. Anderson, B. S. Ellis,
and D. J. Christian

Work performed

by

Health Physics Division
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee

FEBRUARY 1977

for

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

as part of

The Radiological Surveys of Former
Manhattan Engineering District/
Atomic Energy Commission Sites

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

This report needs a figure similar to Fig 1 showing the facility as it exists today + indicating the grid area + locations of sampling points off grid.

RADIOLOGICAL SURVEY OF THE SIMONDS SAW & STEEL COMPANY*

R. W. Leggett
D. L. Anderson
J. Burden
B. S. Ellis
M. T. Ryan
D. J. Christian

We also need a designation of the areas that need to be cleaned and volumes of material to be removed to meet:
1 - appropriate standards
2 ALAP

A separate figure may be needed to show sampling points inside the building.

Abstract

The results of a radiological survey of the Simonds Saw & Steel Company, Lockport, New York, are presented in this report. During the period 1948-1956, this company handled large quantities of uranium metal and smaller quantities of thorium metal in rolling mill operations. The survey included measurement of residual alpha and beta-gamma radiation levels in the rolling mill building and forging shop; external gamma radiation in the same area; uranium, radium, and thorium in soil samples taken from beneath removable floor plates in the rolling mill area and from other parts of the site; radon and radon daughter concentrations in the rolling mill building; and contamination in drainage paths leading from the buildings and grounds. Elevated concentrations of uranium were found in soil samples taken from beneath the floor plates within 40 feet of the 16-inch rolling mill. Beta-gamma radiation levels were greater than 1 mrad/hr at the locations having the highest concentrations of uranium. External gamma radiation levels were above the background level in a few small isolated areas in the rolling mill building.

---

*Research sponsored by the Energy Research and Development Administration under contract with Union Carbide Corporation.

Introduction

At the request of the Energy Research and Development Administration (ERDA), Oak Ridge Operations, a radiological survey was conducted in Lockport, New York, at the Simonds Saw & Steel Company. This company performed rolling mill operations on uranium metal from 1948 through 1956. The first of two contracts with Simonds Saw & Steel Company was negotiated with the New York Operations Office of the U. S. Atomic Energy Commission (AEC). Until the termination of this contract in 1952, Simonds processed 500,000 to 600,000 pounds of uranium per month through the 16-in. bar mill. The second contract was a subcontract with National Lead of Ohio (NLO) who was under contract to the AEC to provide feed material to the Hanford production facility in Richland, Washington. Odd lots which would have required extensive mill changes at the NLO facility were sent to Simonds. During the period 1948 through 1952, approximately 312 rolling mill turns, consisting of 15,000 to 20,000 pounds of material per turn, were made annually. Production decreased to 29 turns in 1953, 56 in 1954, 58 in 1955, and 22 in 1956. Some of the later materials included depleted and 2.5% enriched uranium. Also, about 30,000 to 40,000 pounds of thorium have been processed through Simonds. Over 99% of all of the work performed by Simonds was done on the 16-in. rolling mill. Several small lots of material were run through the 10-in. rolling mill, and some 15 or 20 ingots were processed in the hammer forge shop, which is in an adjacent building.

A plan view of the 16-in. rolling mill and associated facilities is given in Fig. 1. The numbers correspond to process steps; the uranium

flow chart is given in Fig. 2. This flow chart is accurate for 99% of all material processed at Simonds. Ingots or billets of uranium metal were received in boxes or on pallets and placed in area 1. They were uncrated just prior to rolling and were transferred by crane to the weigh station (2)*. After weighing, the ingots were rolled into the lead furnace (3)* which was of a "ferriswheel" type for submerging and carrying the charge through the lead. After heating, the ingots were brought along a roller table to the 16-in. rolling mill (4). Two of the four mill stands of the 16-in. mill were used to roll the uranium. Ingot size determined whether shearing (5) was necessary during rolling. After rolling, the uranium bars were water quenched (6) and then transferred in bundles by crane to the shipping area (7), where they were placed in tared H beams, weighed (8), and loaded into railroad cars from the shipping dock (9).

Before the existence of the lead furnace a few limited heatings were performed in the steel furnaces (10, 11, 14) shown in Fig. 1. Steel sheets lined these furnaces during use, and all have been relined with refractory brick since the period of uranium processing. The forge shop furnace hearths are replaced every eight months, and the side walls are replaced annually. The 10-in. mill furnace was completely rebuilt in 1957 after the termination of all the uranium processing. The normal lifetime of both the 16-in. and 10-in. mill furnace hearths is 1 to 2 years, and the side wall lifetime is 3 to 5 years.

---

*Equipment removed.

During all operations from 1948 through 1956, the AEC was responsible for radiological monitoring and safety. Extensive efforts were made to keep working areas clean. All dross (surface residue) from the lead furnace was skimmed and returned to the AEC or NLO. Protective measures included the use of hoods and dust collection equipment over the 16-in. rolling mill stands and pans in the mill pits to collect material from every working turn. The mill area was vacuumed after every batch of sixteen ingots, and the shipping area was vacuumed daily.

Results of a survey conducted in November 1958 revealed that radiation levels were highest in the quench tank area (6 in Fig. 1.). This tank was removed, and clean steel plates were placed over the area. Other areas in which elevated radiation levels were found were vacuumed and scrubbed with water and detergent. A second radiation survey was conducted in December of 1958 to verify decontamination.

The present survey was undertaken to characterize the existing radiological status of the property. It was conducted by five members of the Health Physics Division of the Oak Ridge National Laboratory on October 9-10 and 16-17, 1976. The survey included:

(1) measurement of external gamma radiation at one meter above the floor of the 16-in. rolling mill and adjacent areas on a 45-ft. square grid and throughout the remainder of the rolling mill building and forging shop;

(2) measurement of beta-gamma radiation on a 15-ft. square floor grid (i.e., sampling points were 15 feet apart) covering the area in which uranium metal had been heated, rolled, and cooled; this was done with the floor plates in place and also with selected floor plates removed;

(3) measurement of uranium, radium, and thorium concentrations in the soil under the removable floor plates;

(4) measurement of alpha and beta contamination levels (fixed and transferable) on surfaces in buildings;

(5) measurement of radon and radon daughter concentrations in air inside the 16-in. rolling mill building;

(6) measurement of contamination of drainage paths from buildings and grounds.

"Contamination", as used in this report, refers to radioactive materials deposited in or on surfaces whether fixed or transferable. Survey meter readings made on surfaces generally indicate the level of fixed contamination while standard smear techniques are used to determine the levels of transferable contamination.

Radiological Survey Techniques

Measurement of Alpha and Beta Contamination Levels

Alpha and beta contamination levels were measured on the floor at each of the grid points at 15-ft. intervals covering the area in which the uranium metal had been heated, rolled, and cooled (Fig. 3). (This area will be referred to throughout the report as the "grid area".) At some grid points, additional direct measurements of alpha and beta contamination were taken underneath the removable steel floor plates (see Figs. 3 and 4). Measurements of fixed and transferable contamination were also taken at other points throughout the rolling mill building and forging shop including walls, elevated support beams and ceilings (see Figs. 3-4 and Tables 1-2).

Fixed alpha contamination levels were measured with alpha scintillation survey meters which are described in Appendix I. Transferable alpha and

beta contamination levels were determined using standard smear techniques. Measurements were made at each of the locations shown in Fig. 6 and at 57 other locations throughout the rolling mill building and forge shop. The smear counters are described in Appendix I.

Measurement of Beta-Gamma Radiation Levels

Beta-gamma dose rates were measured at 1 cm above the surface of the floor at each of the grid points of a 15-ft. square grid covering the same area as the alpha contamination survey discussed above. These measurements were made with Geiger-Muller survey meters described in Appendix I.

Measurement of Radon and Radon Daughter Concentrations in the Rolling Mill Building

For the measurement of instantaneous radon concentrations in the air in the area of the rolling mills, air samples were taken using evacuated 95-ml glass flasks (known as Lucas chambers) coated with a uniform layer of zinc sulfide. Sample counting was delayed for 3 to 4 hours to allow the radon daughters to attain equilibrium. Each chamber was placed in light-tight contact with a photomultiplier and counted for 1000 seconds. A calibration performed at ORNL using a known radon concentration indicated that the detection efficiency for the Lucas-chamber counting system is 2.02 pCi/l per cpm. The Lucas chamber and photomultiplier tube are shown in Appendix II.

Air samples were also taken in the vicinity of the rolling mills for the measurement of radon daughters. Air was pumped for five minutes

at approximately 12 liters per minute through a membrane filter with a maximum pore size of 0.4 μ. The filter was counted using an alpha spectrometry technique refined by Kerr.[1] This technique is described in Appendix II.

Measurements of External Gamma Radiation Levels

External gamma radiation levels were measured with scintillation survey meters which are described in Appendix I. Readings were taken at one meter above the surface at intervals of 30 to 45 feet in the grid area (shown in Fig. 5) and at the locations listed in Table 3. Scintillation survey meter measurements are indicative of the instantaneous exposure rates at the point of measurement.

Measurement of Uranium, Radium, and Thorium Concentrations in Soil

Soil samples were taken from the ore storage area, from beneath the removable floor plates in the grid area (see Fig. 3), and from other locations inside the rolling mill building. Samples were also collected outdoors, within a few feet of the rolling mill building. The samples were packaged in plastic bags before being returned to Oak Ridge, where they were dried for 24 hours at 110°C and then pulverized to a particle size of -35 mesh (500 μm). Next, aliquots from each sample were transferred to plastic bottles, weighed, and counted using a Ge(Li) detector. The spectra obtained were analyzed by computer techniques. A description of the Ge(Li) detector and the soil counting techniques is given in Appendix III. Uranium, radium, and thorium concentrations were determined for all samples. Two samples were analyzed for concentrations of individual uranium isotopes using mass spectrometry techniques.

Measurement of Radioactivity in Surface Water

Water samples were taken from the drainage of the mill building and from a nearby canal which served as the outfall for rolling mill coolant water. In addition, a tap-water sample was taken from the city water system. The samples were analyzed at ORNL using radiochemistry techniques.

Survey Results

Results of Soil Sample Analyses

Concentrations of uranium (^{238}U), radium (^{226}Ra), and thorium (^{232}Th) in soil samples collected on the site are listed in Table 4. Locations of outdoor soil samples are indicated in Fig. 1, and grid points referred to in Table 4 can be found in Fig. 3. Three samples taken from the surface beneath the removable floor plates in the area near the 16-in. rolling mill showed concentrations of uranium in excess of 10,000 pCi/g. Samples collected outside the grid area showed uranium concentrations from 1.8 to 50 pCi/g, except for sample S3 (see Table 4 and Fig. 1), which contained 620 pCi/g of uranium. This sample was taken outdoors near the southern entrance to the rolling mill building. Because some enriched uranium had been processed at this facility, two samples (5F-1 and 11E) were analyzed for the concentrations of individual uranium isotopes ^{234}U, ^{235}U, ^{236}U, and ^{238}U. Mass spectrometry techniques were used to provide this information. Results of this analysis (see Table 5) revealed an isoptic ratio equivalent to natural uranium deposits.

Radium concentrations in the 29 soil samples were no higher than 1.1 pCi/g. These low concentrations of radium were to be expected, since there has not been sufficient time for significiant ingrowth of radium from the initially pure uranium, and since no uranium ore was processed at Simonds.

The highest concentration of thorium found in soil samples was 11 pCi/g. Twenty-two of the 25 samples collected inside the building showed thorium concentrations of less than 3 pCi/g. In most samples, the activity of thorium was less than 1% of the activity of uranium.

Alpha and Beta Contamination Levels

Direct measurements of alpha contamination levels taken in the 16-in. rolling mill building and in the forging shop are given in Table 1 and Fig. 3. Direct readings of alpha contamination levels taken outside the grid area were in the range of 0-60 dpm/100 cm^2 (see Table 1). Alpha contamination levels in the grid area were as high as 4600 dpm/100 cm^2 by direct reading, with the highest readings being recorded within 20 feet of the 16-in. rolling mill (see Fig. 3). Most of the contamination was found on or under the floor plates. Direct readings of alpha contamination on walls, beams, rafters, and ceilings were in the range of 0-60 dpm/100 cm^2. According to guidelines issued by the United States Nuclear Regulatory Commission (USNRC)[2] for the release of property for unrestricted use, average and maximum acceptable levels* of alpha contamination on surfaces are 5000 dpm/100 cm^2 and 15,000 dpm/100 cm^2, respectively, provided the radioactive contaminant is natural uranium. This is also consistent with a proposed ANSI standard[3]. The radioactive materials processed on the site were natural uranium and natural thorium, and there has been sufficient time for ^{228}Ra (with a half-life of 6.7 years) to attain almost complete radioactive equilibrium with its parent,

---

*Measurements may not be averaged over more than 1 square meter. The maximum contamination level applies to an area of not more than 100 cm^2.

^{232}Th. Furthermore, for surfaces contaminated with ^{228}Ra, the USNRC average and maximum allowable limits of alpha contamination are 100 dpm/100 cm^2 and 300 dpm/100 cm^2, respectively. Hence, the standards for ^{228}Ra are 50 times more restrictive than those for natural uranium. However, it appears from the relative activities of ^{238}U and ^{232}Th in soil samples from Simonds that the standard for natural uranium is the appropriate standard to be applied to this site. At 14 of the points of measurement in the rolling mill building (all 14 in the grid area), alpha radiation was higher than 100 dpm/100 cm^2 by direct reading (see Fig. 3), either on the floor plates or open dirt, or on the soil beneath the removable floor plates. Soil samples were taken from beneath the floor plates at 9 of these 14 locations (see Table 4 and Fig. 3); and in 8 of these 9 soil samples, ^{238}U concentrations were at least 100 times as much as ^{228}Ra concentrations (assuming equilibrium of ^{232}Th and ^{228}Ra). At location 11E (Fig. 3), where alpha contamination in the open dirt was 310 dpm/100 cm^2 by direct reading, the activity of ^{238}U was about 38 times the activity of ^{228}Ra (assuming equilibrium of ^{232}Th and ^{228}Ra). Hence it is reasonable to assume that less then 3% (or 10 dpm/100 cm^2) of the total alpha activity at this location is from ^{228}Ra.

Smear samples were taken at the locations given in Fig. 6 and at 57 other locations throughout the rolling mill building and forging shop including walls, beams, rafters, and ceilings. None of the smears showed alpha contamination in excess of 5 dpm/100 cm^2, and all smears showed less than 100 dpm/100 cm^2 of beta contamination. These levels are well within the allowable limits defined by the USNRC.[2]

Beta-Gamma Radiation Levels

Direct readings of beta-gamma radiation levels are given in Table 2 and Fig. 4. Measurements taken outside the grid area were in the range of 0.01-0.04 mrad/hr (see Table 2), and the measurements on walls, beams, rafters, and ceilings were less than 0.01 mrad/hr. In the grid area (Fig. 4), some readings taken within 40 feet of the 16-in. rolling mill on the floor and on the soil beneath the removable floor plates were above 1.0 mrad/hr. According to USNRC guideline[2] for unrestricted use, the maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 1.0 mrad/hr. The highest beta-gamma radiation level measured was 42 mrad/hr at a point under a floor plate near the old quench tank area (Fig. 4). A sample of this material (see sample 5F-1, Table 4) was returned to Oak Ridge for determination of uranium, radium, and thorium content. Analysis showed a uranium concentration of 21,000 pCi U/g soil (6.3% uranium); no radium or thorium was found in the sample. No significant reduction in the radiation level was noted after removal of the sample.

External Gamma Radiation Levels

Measurements of external gamma radiation levels at one meter above the floor in the rolling mill building and forging shop are given in Fig. 5 and Table 3. Outside the grid area (see Table 3) the maximum reading was 12 μR/hr, which is within the range of background measurements which have been taken in the Lockport area. In the grid area, readings were as high as 48 μR/hr, with highest readings being recorded in an area near the 10-in. furnace (see Fig. 5). This area, which is not

covered by floor plates, has been used for storage of mill rollers for several years, including the period of uranium and thorium operations. An area of not more than 5 m^2 is associated with these elevated gamma readings.

Radon and Radon Daughter Measurements in the Rolling Mill Building

Air samples were taken east and west of the rolling mill area for measurement of radon concentrations. Both samples showed radon concentrations of less than 0.4 pCi/l. Two additional air samples were taken for the measurement of radon daughter concentrations, one approximately 50 meters from the main entrance of the rolling mill building and the other in the rolling mill area. Both samples showed radon daughter concentrations well below 0.001 WL.* These results for radon and radon dauger concentrations are consistent with the fact that only small quantities of radium, the parent of radon, were found in the building.

Results of Water Sample Analyses

Concentrations of uranium, radium, and thorium in water samples taken on and near the site are listed in Table 3, which also gives the maximum permissible concentrations (MPC's) for each radionuclide tested. Sample 1 is a tap-water sample taken from the city water system, sample 2 was taken from a nearby canal which served as the outfall for rolling mill coolant water, and sample 3 was taken from the drainage from the mill building. In each sample, the concentration of each radionuclide tested was at least an order of magnitude below the MPC_w (4).

*A working leve (WL) is defined as any combination of short lived radon daughters in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha particle energy.

Summary

The site was used for rolling mill processing of large quantities of uranium metal and relatively small quantities of thorium metal during the period 1948-1956. High concentrations of uranium were found in soil samples taken throughout the rolling mill building. Samples taken from beneath the removable steel floor plates near the 16-in. roll mill showed ^{238}U concentrations as high as 21,000 pCi/g. It should be noted that the specific activity of ^{238}U is 3.33×10^{-7} Ci $^{238}U/g^{238}U$; therefore this sample of soil contains:

$$\frac{2.10 \times 10^{-8} \text{ Ci/g soil}}{3.33 \times 10^{-7} \text{ Ci/g U}} \quad \text{or } 0.063 \text{ g } ^{238}U/\text{g soil.}$$

This is equivalent to 6.3% uranium in the soil and exceeds the 0.05% uranium requiring a source material license[5]. This latter value is equivalent to 172 pCi ^{238}U/g soil. It is seen in Table 4 that 55% of the samples contain uranium in excess of the "source material" level. Concentrations of uranium found in five samples taken from in and around the ore storage area ranged from 5.8 to 50 pCi/g. One soil sample taken from a section of the rolling mill building remote to the uranium operations contained a uranium concentration of 13 pCi/g, and a sample taken near an entrance of the rolling mill building contained 620 pCi/g uranium. The highest concentration of thorium found in any sample was 11 pCi/g. Normal background concentrations of ^{238}U, ^{226}Ra and ^{232}Th are approximately 1 pCi/g each.

After 20-28 years, the ingrowth of ^{226}Ra from the natural uranium is negligibly small, but ^{228}Ra (with a 6.7 year half-life) has had

sufficient time to attain 85-95% equilibrium with its parent, ^{232}Th. However, the large ratio of uranium activity to thorium activity in soil samples taken on the site indicate that in applying surface contamination guidelines provided by the USNRC, the standards for natural uranium should be used. Under this standard, the levels of residual alpha radiation measured on the site are considered acceptable. However, some direct readings of beta-gamma radiation taken on the floor and underneath the removable floor plates near the 16-in. rolling mill exceeded 1 mrad/hr, which is the maximum allowable for unrestricted use according to the USNRC guidelines[2]. Transferable alpha and beta radiation levels on the site appear to be low; all smears showed less than 10 dpm/100 cm^2 alpha contamination and less than 100 dpm/100 cm^2 beta contamination.

External gamma radiation levels inside the rolling mill building near the 16-in. rolling mill were as high as 48 μR/hr. An individual exposed to this gamma radiation level for 40 hours each week would realize an integrated dose equivalent of approximately 100 mrem/yr. However, the areas associated with the high readings were small. In most areas inside the building, external gamma radiation was near background levels.

It appears from the survey results that there is no potential problem from radon and radon daughters in the building. This is supported by the findings of only small traces of ^{226}Ra in samples.

In water samples taken from the drainage from the site, the concentrations of uranium, radium, and thorium were at least an order of magnitude below the maximum permissible concentrations.

References

1. G. D. Kerr, Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectroscopy, ORNL-TM-4924, 1975.
2. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source, or Special Nuclear Material, U. S. Nuclear Regulatory Commission, December, 1975.
3. Proposed American National Standard, ANSI N328-197, "Control of Radioactive Surface Contamination of Materials, Equipment and Facilities to be Released for Uncontrolled Use," 1976.
4. Code of Federal Regulations, Title 10, Part 20, "Standards for Protection Against Radiation," Appendix B.
5. Code of Federal Regulations, Title 10, Part 40, "Licensing of Source Material".

Reference prior surveys

Table 1. Direct Readings of Alpha Contamination Levels in Buildings Off the Grid Area

Location	Number of Readings	Maximum Reading (dpm/100 cm^2)	Average Reading (dpm/100 cm^2)	Experimental Standard Dev. (dpm/100 cm^2)
Uranium storage area	12	55	35	15
Forging shop	13	25	10	8
Grinding area	2	45	35	10
South of storage area	3	60	35	28
Southwest bay	8	30	10	10
West central bay	2	20	20	0
South of 10 in. roll mill	3	25	15	7
Northwest bay (north of grid area)	14	60	20	7

Table 2. Direct Readings of Beta-Gamma Radiation Levels in Buildings Off the Grid Area

Location	Number of Readings	Maximum Reading (mrad/hr)	Average Reading (mrad/hr)	Experimental Standard Dev. (mrad/hr)
Uranium storage area	12	0.04	0.02	0.01
Forging shop	13	0.03	0.02	0.01
Grinding area	2	0.02	0.02	< 0.01
South of storage area	3	0.04	0.03	0.01
Southwest bay	8	0.04	0.02	0.01
West central bay	2	0.04	0.04	< 0.01
South of 10" roll mill	3	0.04	0.03	0.01
Northwest bay (north of grid area)	14	0.04	0.02	0.01

Table 3. External Gamma Radiation Levels at 1 Meter Above Surface in Buildings, Off the Grid Area

Location	Number of Readings	Maximum Reading (μR/hr)	Average Reading (μR/hr)	Experimental Standard Dev. (μR/hr)
Uranium storage area	12	8	6	1
Forging shop	13	6	5	1
Grinding area	2	6	5	1
South of storage area	3	7	6	2
Southwest bay	8	10	6	2
West central bay	2	10	10	0
South of 10 in. roll mill	3	12	8	4
Northwest bay (north of grid area)	14	8	5	1

Table 4. Concentrations of ^{238}U, ^{232}Th, and ^{226}Ra in Soil Samples

Sample	Location*	Depth	^{238}U (pCi/g)	^{232}Th (pCi/g)	^{226}Ra (pCi/g)
1C	grid point 1C	surface	1230	11.0	not found
2D	grid point 2D	surface	520	2.1	not found
3C	grid point 3C	surface	250	not found	not found
3D-1	grid point 3D	6 in.	420	not found	not found
3D-2	grid point 3D	12 in.	180	0.9	0.9
3E	grid point 3E	surface	110	0.3	not found
4C	grid point 4C	surface	730	2.1	not found
4D	grid point 4D	surface	310	1.5	not found
4E	grid point 4E	surface	210	2.1	not found
5C	grid point 5C	surface	10,000	8.4	not found
5F-1	grid point 5F	surface	21,000	not found	not found
5F-2	grid point 5F	6 in.	85	not found	not found
5F-3	grid point 5F	12 in.	190	not found	not found
6C-1	grid point 6C	surface	10,000	not found	not found
6C-2	grid point 6C	6 in.	920	not found	not found
6C-3	grid point 6C	12 in.	31	0.3	not found
6D	grid point 6D	surface	900	2.5	not found
11E	grid point 11E	surface	370	9.6	not found

*All samples collected at grid points were taken from below removable floor plates.

Table 4 (cont'd) Concentrations of ^{238}U, ^{232}Th, and ^{226}Ra in Soil Samples

Sample	Location*	Depth	^{238}U (pCi/g)	^{232}Th (pCi/g)	^{226}Ra (pCi/g)
B1	South of ore storage area	surface	25	0.5	0.7
B2	North of ore storage area	surface	50	0.7	not found
B3	West of ore storage area	surface	9.0	0.5	0.3
B4	East of ore storage area	surface	8.1	0.8	0.5
B5	Center of ore storage area	surface	5.8	0.6	0.3
NE6	NE part of building	surface	not found	not found	1.1
SE7	SE part of bldg.	surface	13	0.8	not found
N1	<10' N of roll mill bldg.	surface	6.1	0.8	0.7
E2	<10' E of roll mill bldg.	surface	1.8	0.4	not found
S3	near S entrance of roll mill bldg.	surface	620	not found	not found
W4	<10' W of roll mill bldg.	surface	4.7	0.7	0.6

Table 5. Mass Spectrometry Analysis of Residual Uranium in Soil

SAMPLE NUMBER	WT. PERCENT URANIUM	ATOM PERCENT ^{234}U	^{235}U	^{236}U	^{238}U
5F-1	0.1	0.0052	0.71	<.001	99.28
11-E	6.73	0.0054	0.71	<.001	99.28

Table 6. Results of Water Sample Analyses
(measurements given in pCi/ml)

Sample	^{228}Th	^{230}Th	^{224}Ra	^{226}Ra	^{234}U	^{238}U
1	7.2×10^{-4}	3.6×10^{-5}	$<1.2 \times 10^{-3}$	$<1.2 \times 10^{-3}$	2.3×10^{-4}	1.8×10^{-4}
2	1.9×10^{-3}	$<5 \times 10^{-5}$	$<1.7 \times 10^{-3}$	$<1.7 \times 10^{-3}$	1.5×10^{-3}	1.4×10^{-3}
3	6.3×10^{-4}	5.9×10^{-4}	$<1.8 \times 10^{-3}$	$<1.8 \times 10^{-3}$	1.1×10^{-3}	9.0×10^{-4}
MPC_w (soluble)	7	2	2	3×10^{-2}	30	40

Numbers in circles correspond to process steps.
FCE - Furnace.

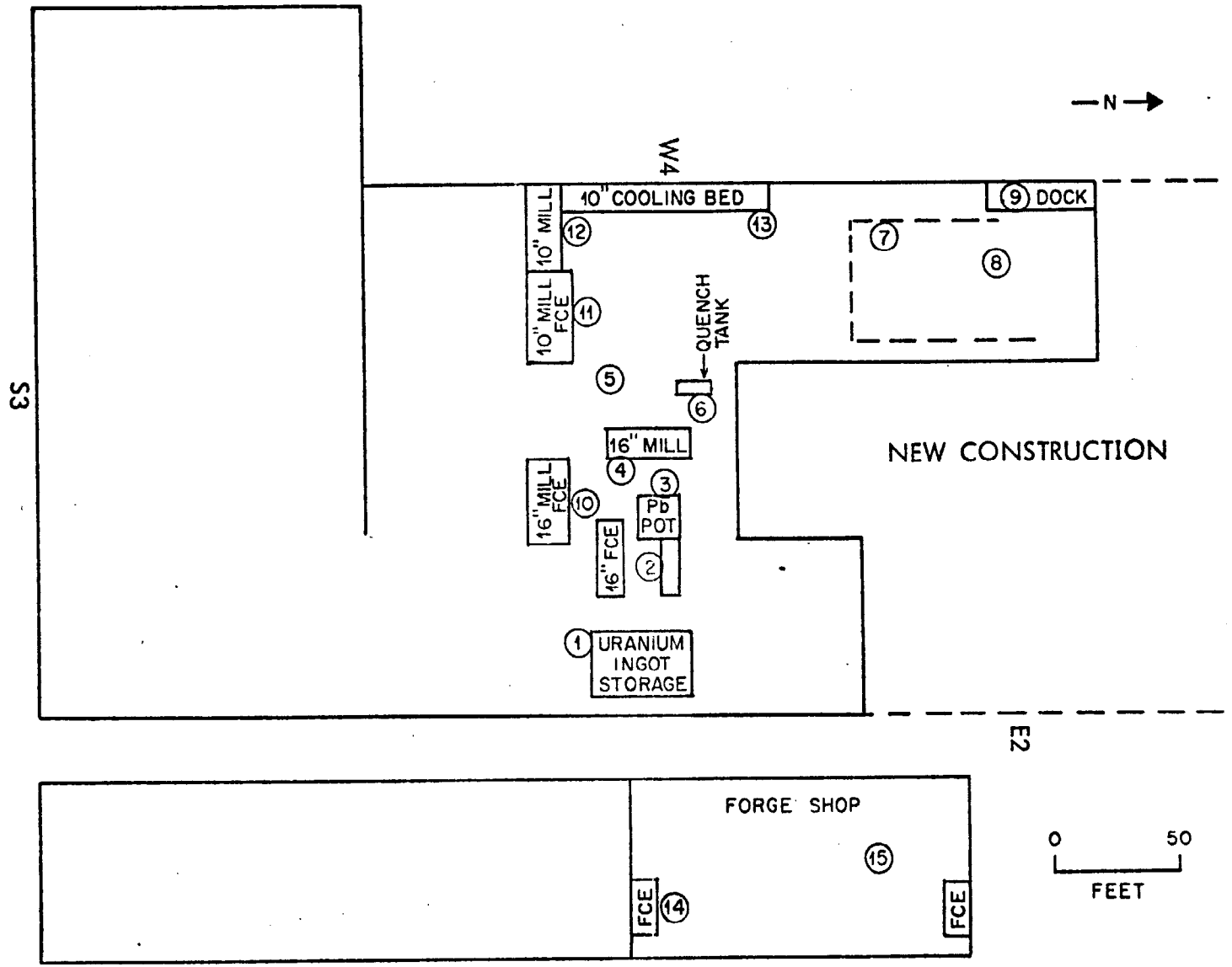
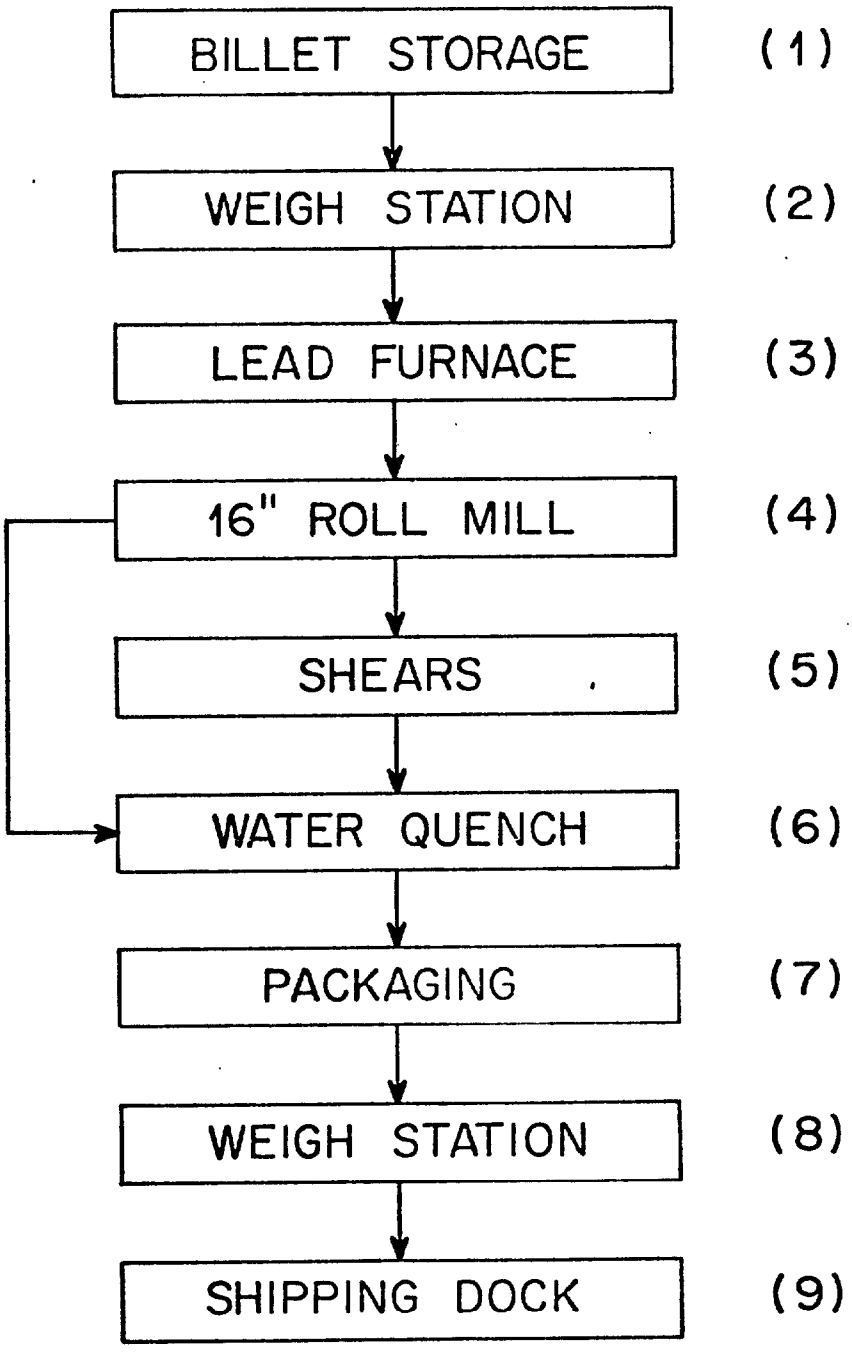
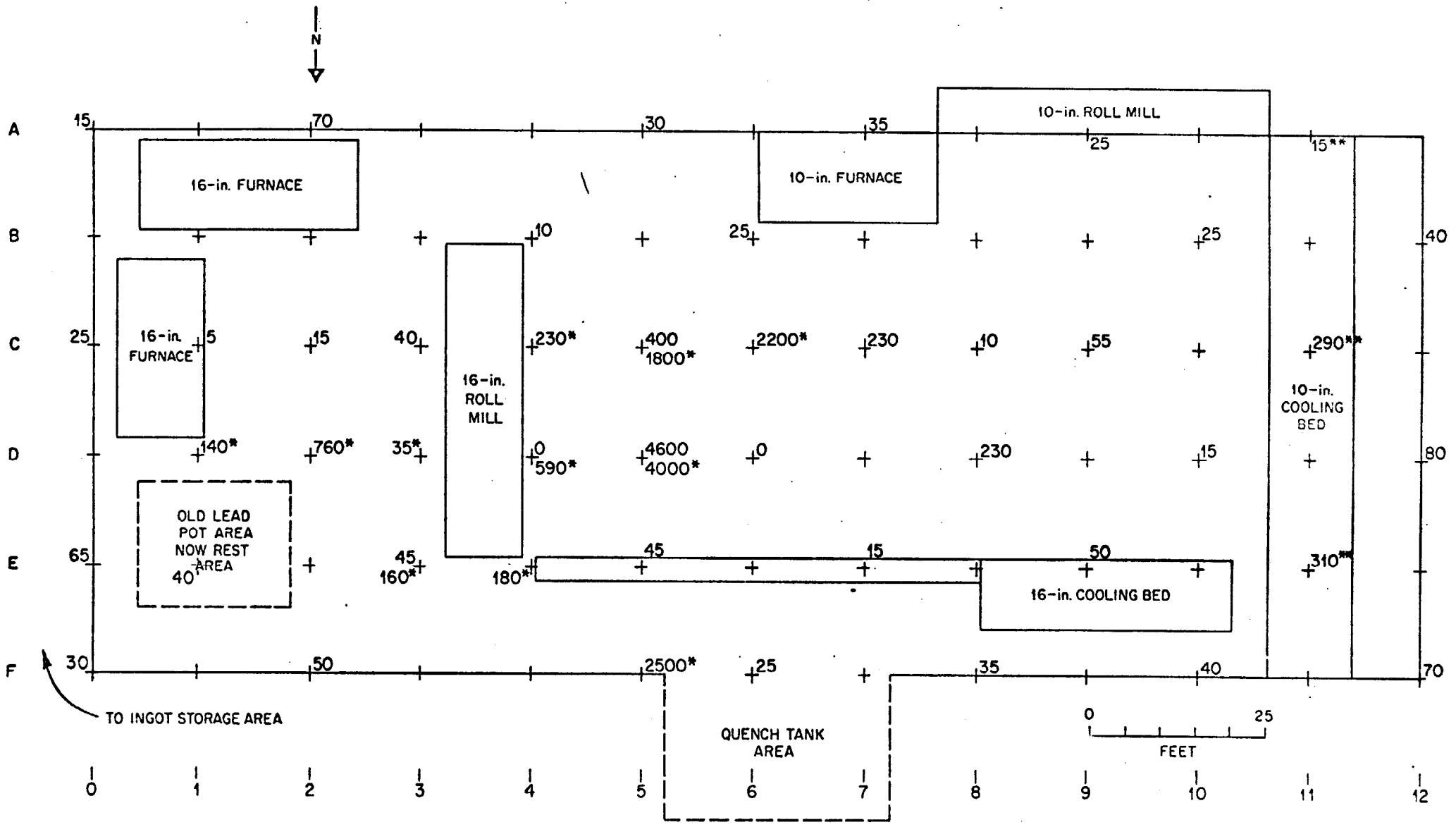


Fig. 1. Plan View of the 16-in. Roll Mill and Forge Shop.



URANIUM FLOW CHART

Fig. 2. Flow Chart Describing Path of Uranium During Operations at Simonds.



READINGS GIVEN IN DPM/100 cm^2

* UNDER REMOVABLE FLOOR PLATES

** IN OPEN DIRT

Fig. 3. Direct Readings of Alpha Radiation Levels on Floor in Rolling Mill Area.

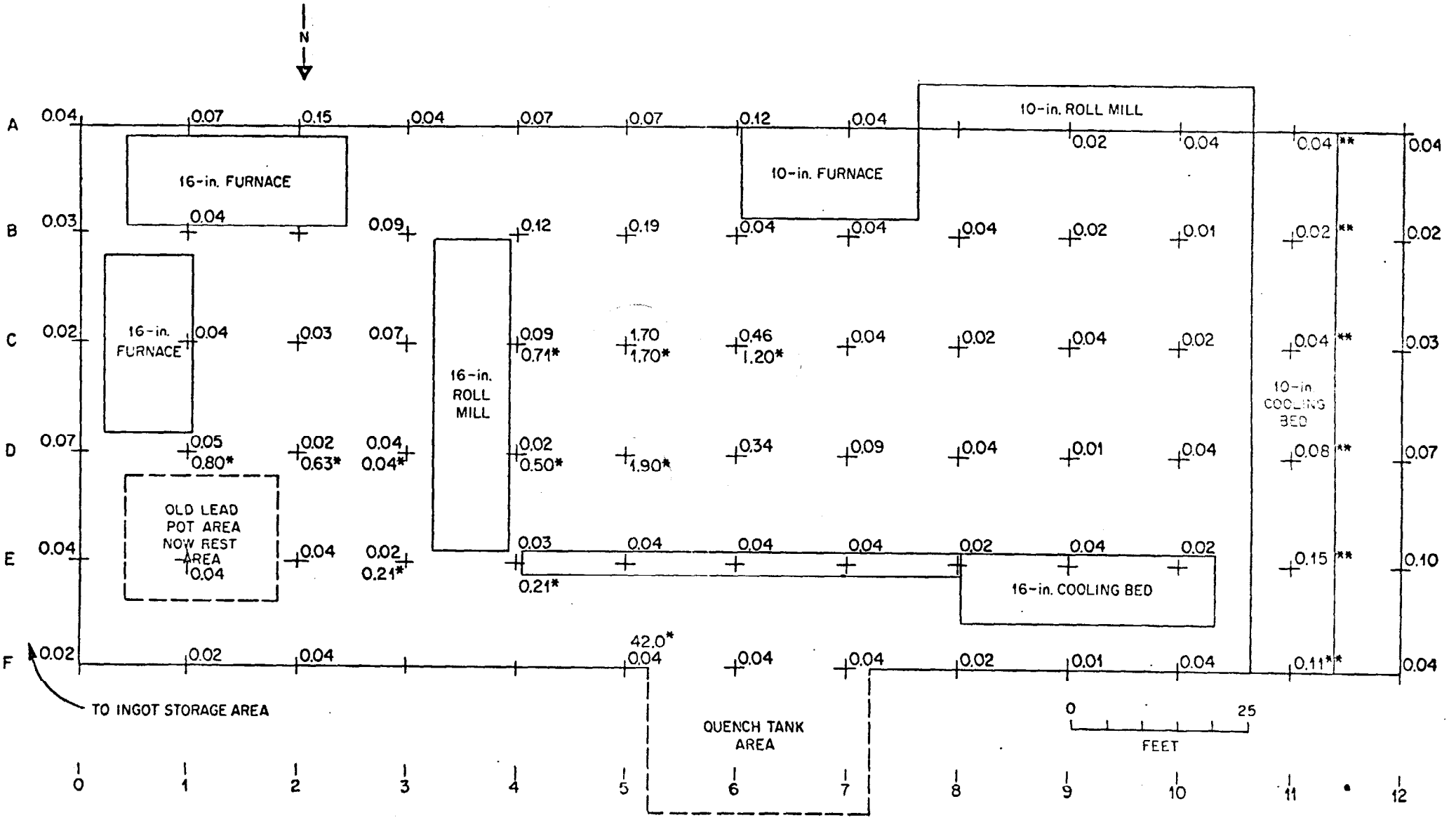


Fig. 4. Direct Readings of Beta-Gamma Radiation Levels on Floor in Rolling Mill Area.

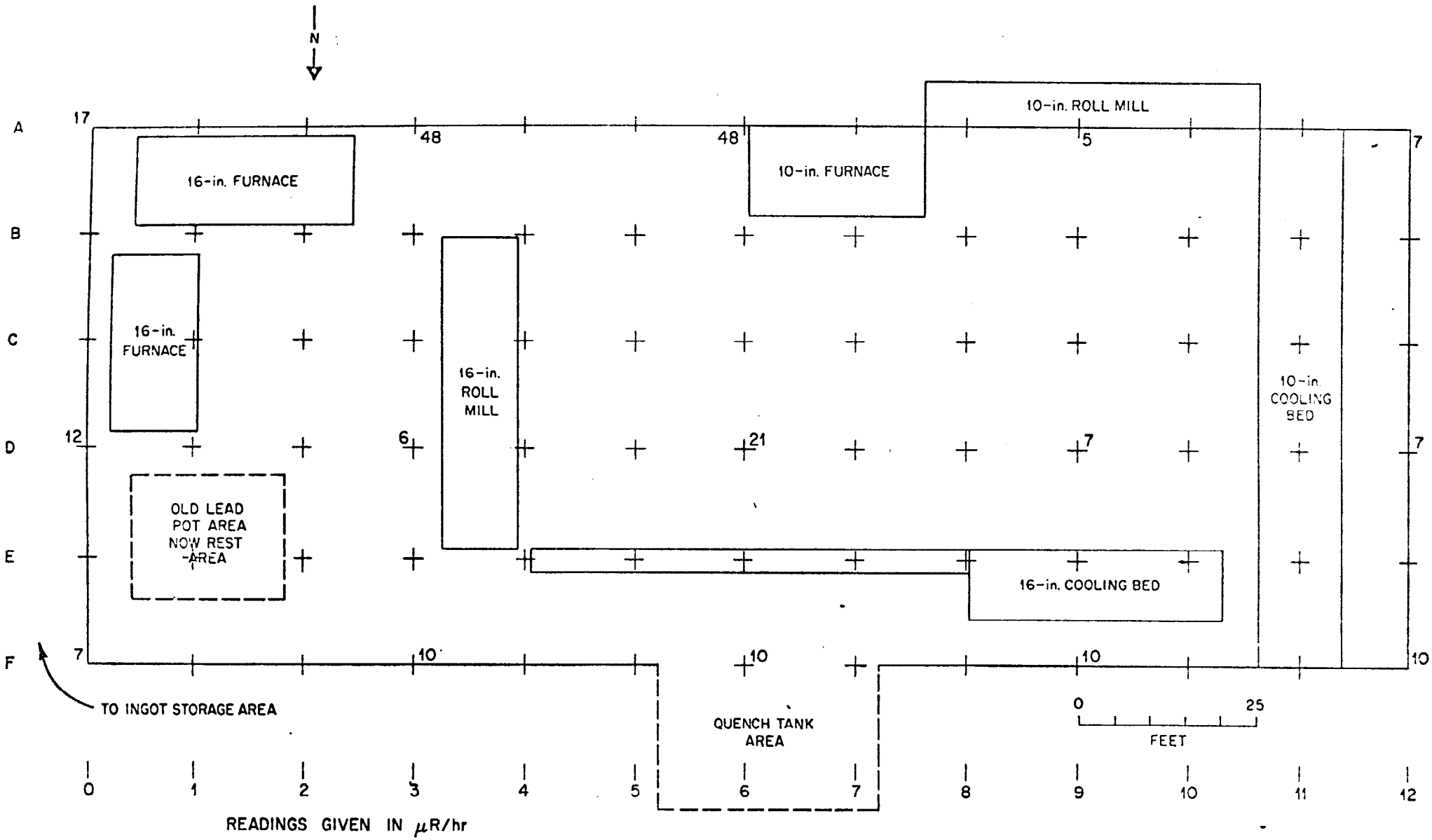


Fig. 5. External Gamma Radiation Levels in Rolling Mill Area.

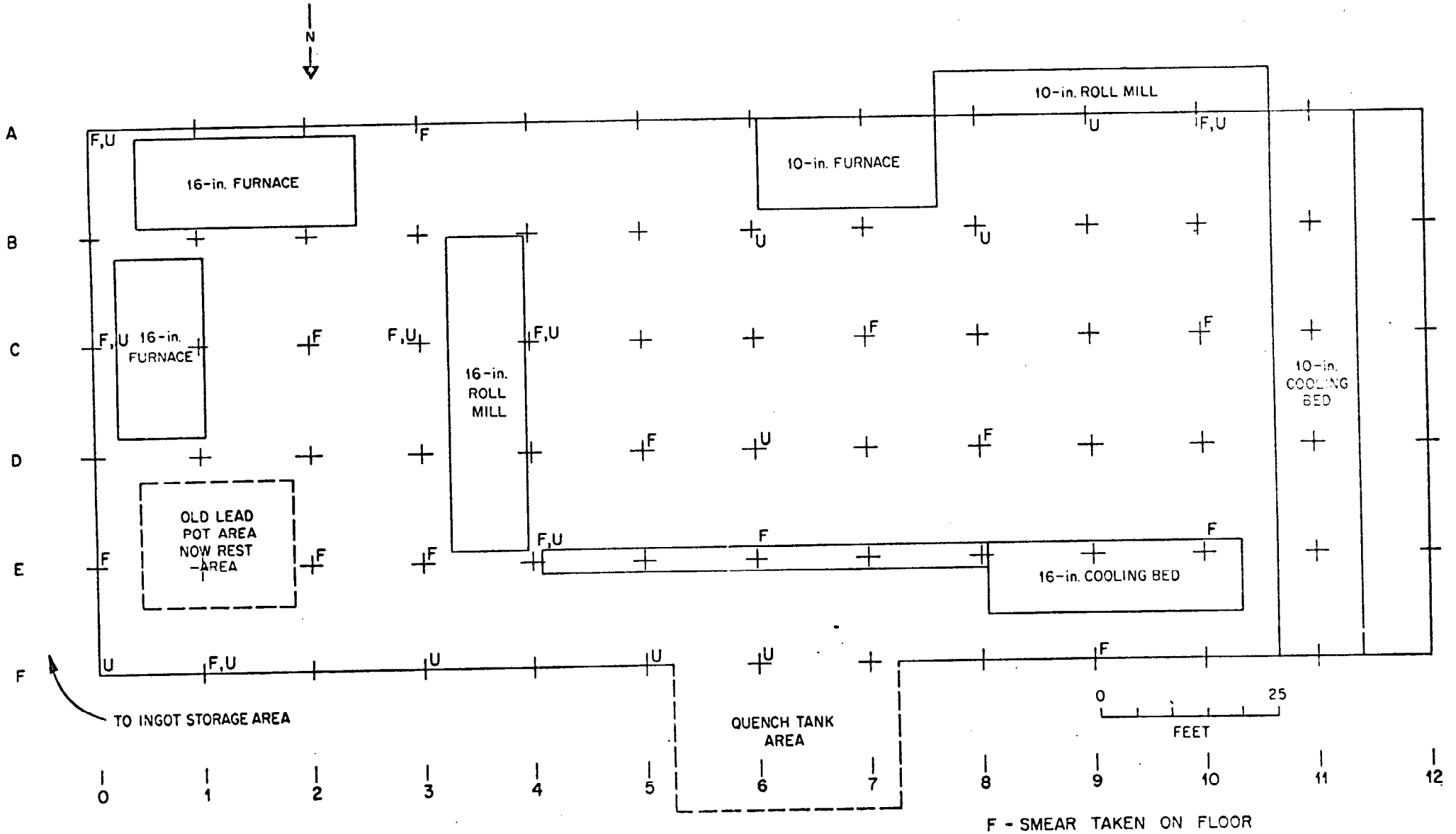


Fig. 6. Locations at which Smear Samples Were Taken in Rolling Mill Area.

APPENDIX I

DESCRIPTION OF RADIATION SURVEY METERS AND SMEAR COUNTERS

RADIATION SURVEY METERS

Alpha Survey Meters

Two types of alpha survey meters are used to measure alpha radioactivity on surfaces. One type of instrument uses a ZnS scintillator and the other uses a gas-flow proportional counter to detect the alpha radiation.

The alpha scintillation survey meter consists of a large area (100 cm^2) ZnS detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (see Fig. I-A). The ZnS detector is covered with a 5-mil aluminized mylar sheet in order to make the instrument light-tight. The mylar, in turn, is covered with a grid to prevent puncturing the detector when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few dpm/100 cm^2 but must be used in the scaler mode for this purpose. It is highly selective for densely ionizing radiation such as alpha particles; the instrument is relatively insensitive to beta and gamma radiation.

The gas-flow proportional counter uses propane gas as the detection medium. Through front panel meter readings, it can be used to measure alpha contamination levels from a few hundred dpm/100 cm^2 to several hundred thousand dpm/100 cm^2. If individual pulses are counted, this instrument can also be used for measurements down to a few d/m-100 cm^2. The probe has a surface area of approximately 61 cm^2 and has a 2.5 mil aluminized mylar covering with a protective grid. Due to the protective grid, the active area of the probe is 50 cm^2. It is relatively insensitive to other than alpha radiation. This instrument, shown in Fig. I-B, is manufactured by the Eberline Instrument Company as their model PAC-4G meter with a probe.

Both of these instruments are calibrated at ORNL using ^{239}Pu alpha sources. While each instrument is individually calibrated, the calibration factors are typically 5-6 dpm/cpm.

Beta Survey Meter

A portable Geiger-Muller (G-M) survey meter is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a 30 mg/cm^2 wall thickness and presenting a cross-sectional area of approximately 10 cm^2. Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open window and a closed-window configuration. Beta radiation cannot penetrate the closed window,, and, thus, the beta reading can be determined by taking the difference between the open and closed window readings. This meter is shown in Fig. I-C.

The G-M survey meter was calibrated at ORNL for gamma radiation using an NBS standard Ra source. The gamma calibration factor is typically of the order of 2600 cpm/mR/hr.

In order to assess beta-gamma surface dose rates from uranium contaminated surfaces using this instrument, a field calibration was performed. The G-M survey meter was compared with a Victoreen Model 440 ionization chamber (see Fig. I-D) and was found to produce 2400 cpm/mrad/hr (from a best-fitting line with a coefficient of determination of $r^2 = 0.90$) for a wide variety of surfaces.

Gamma Scintillation Survey Meter

A portable survey meter using a NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2 x 3.8-cm NaI crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (see Fig. I-E).

This unit is capable of measuring radiation levels from a few μR/hr to several hundred μR/hr. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are of the order of 300 cpm/μR/hr.

SMEAR COUNTERS

Alpha Smear Counter

This detector assembly, used for the assay of alpha emitters on smear paper samples, consists of a light-tight sample holder, a zinc sulfide phosphor and a photomultiplier tube. This detector assembly was used with electronic components housed in a portable NIM bin (see Fig. I-F). The electronics package consisted of a preamplifier, a ORTEC 456 high voltage power supply, a Tennelec TC 211 linear amplifier and a Tennelec TC 545 counter-timer.

The alpha smear counter was used in the field and was calibrated daily using an alpha source with a known disintegration rate.

Beta Smear Counter

The beta smear counter consisted of a thin mica window ($\sim$ 2 mg/cm^2) G-M tube mounted on a sample holder and housed in a 23-cm diam x 35-cm high lead shield. Located under the counter window is a slotted sample holder, accessible through a hinged door on the shield. An absorber can be interposed in the slot between the sample and the counter window to determine relative beta and gamma contributions to the observed sample counting rate. The electronics for this counter were housed in a portable NIM bin and consisted of a Tennelec TC 148 preamplifier, an ORTEC 456 high voltage power supply and a Tennelec TC 545 counter-timer.

This unit, shown in Fig. I-F, was used in the field to measure beta activity on smear papers and was calibrated daily using a beta standard of known activity.

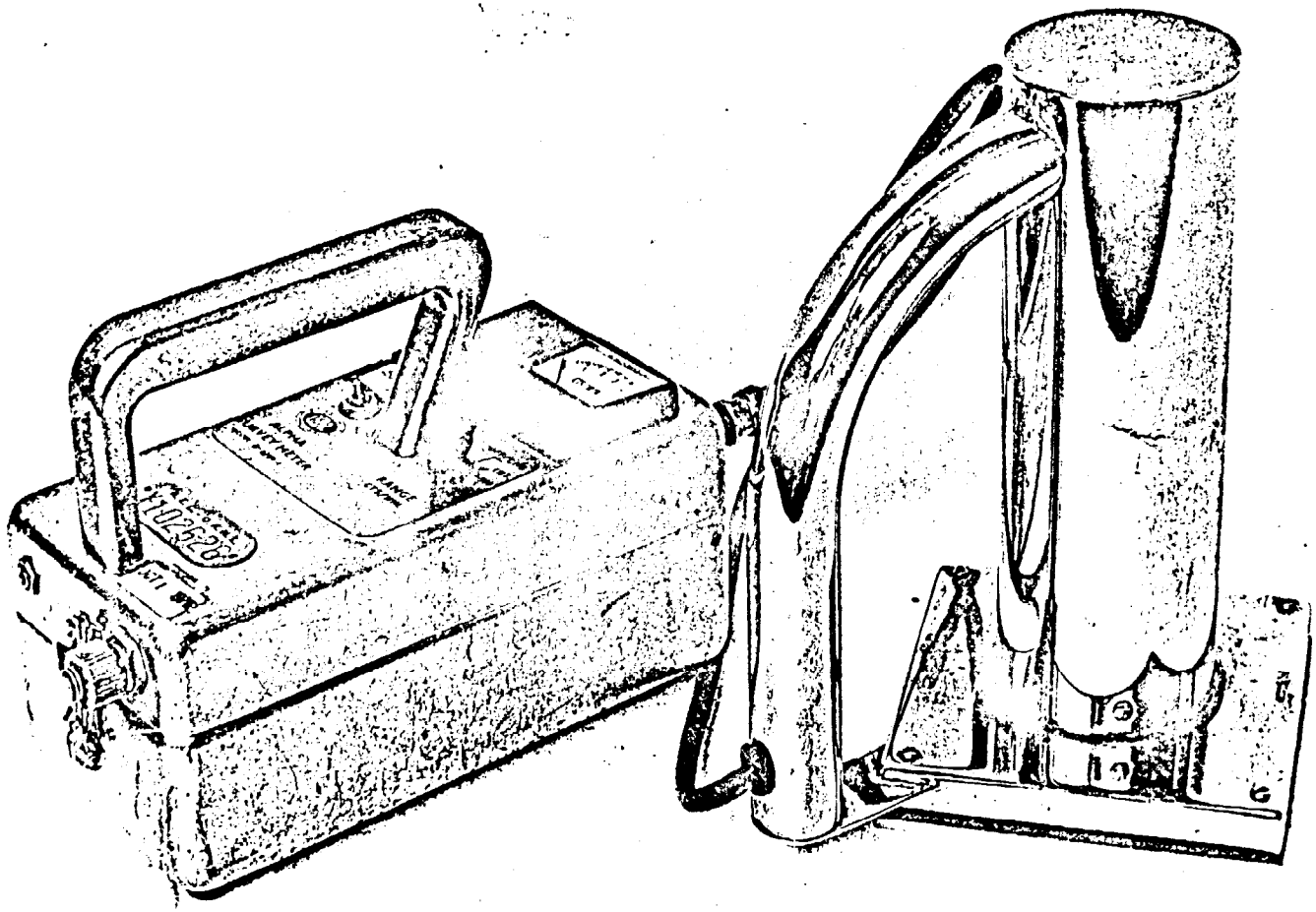


Fig. I-A Alpha Scintillation Survey Meter

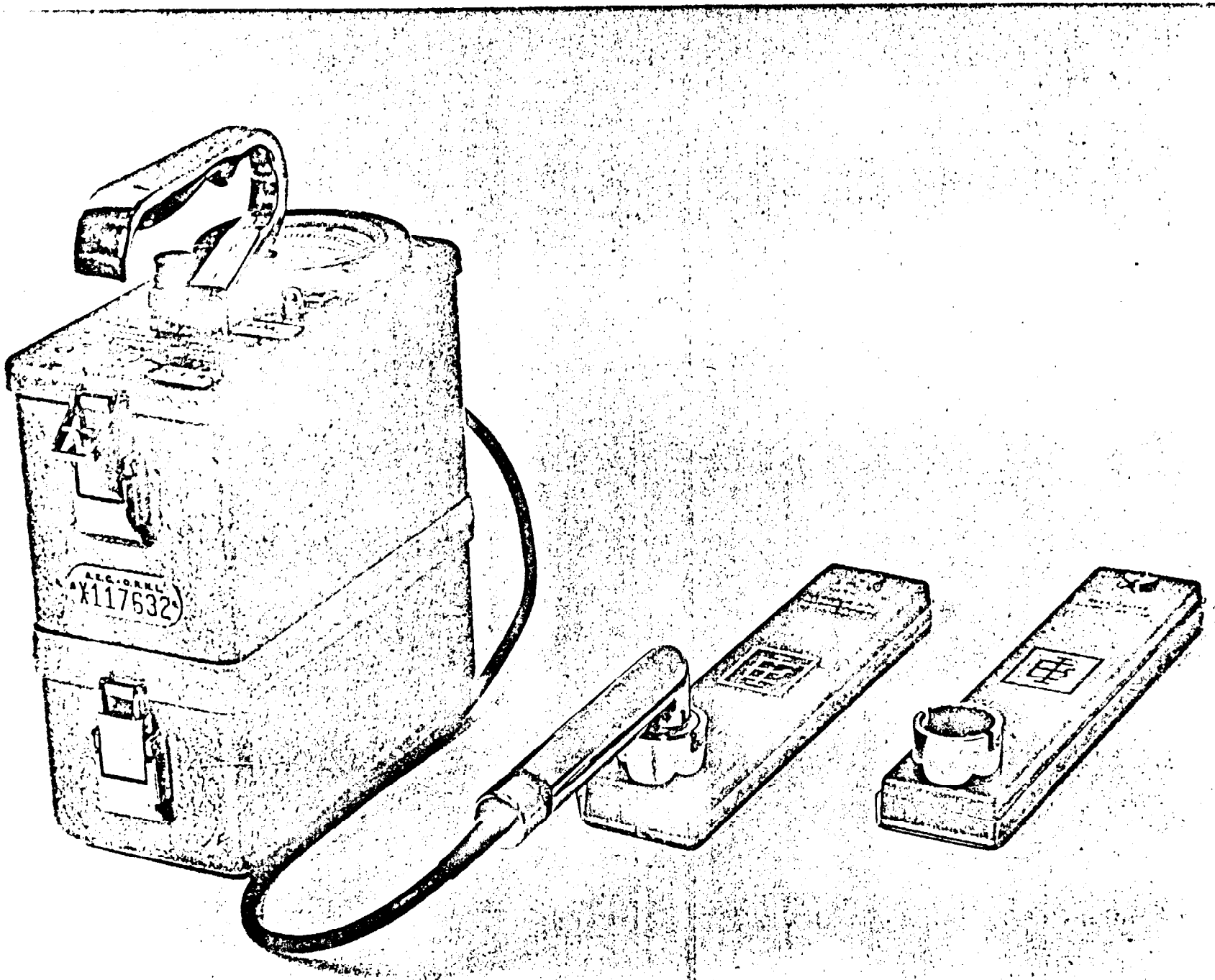


Fig. I-B Gas-flow Proportional Alpha Survey Meter

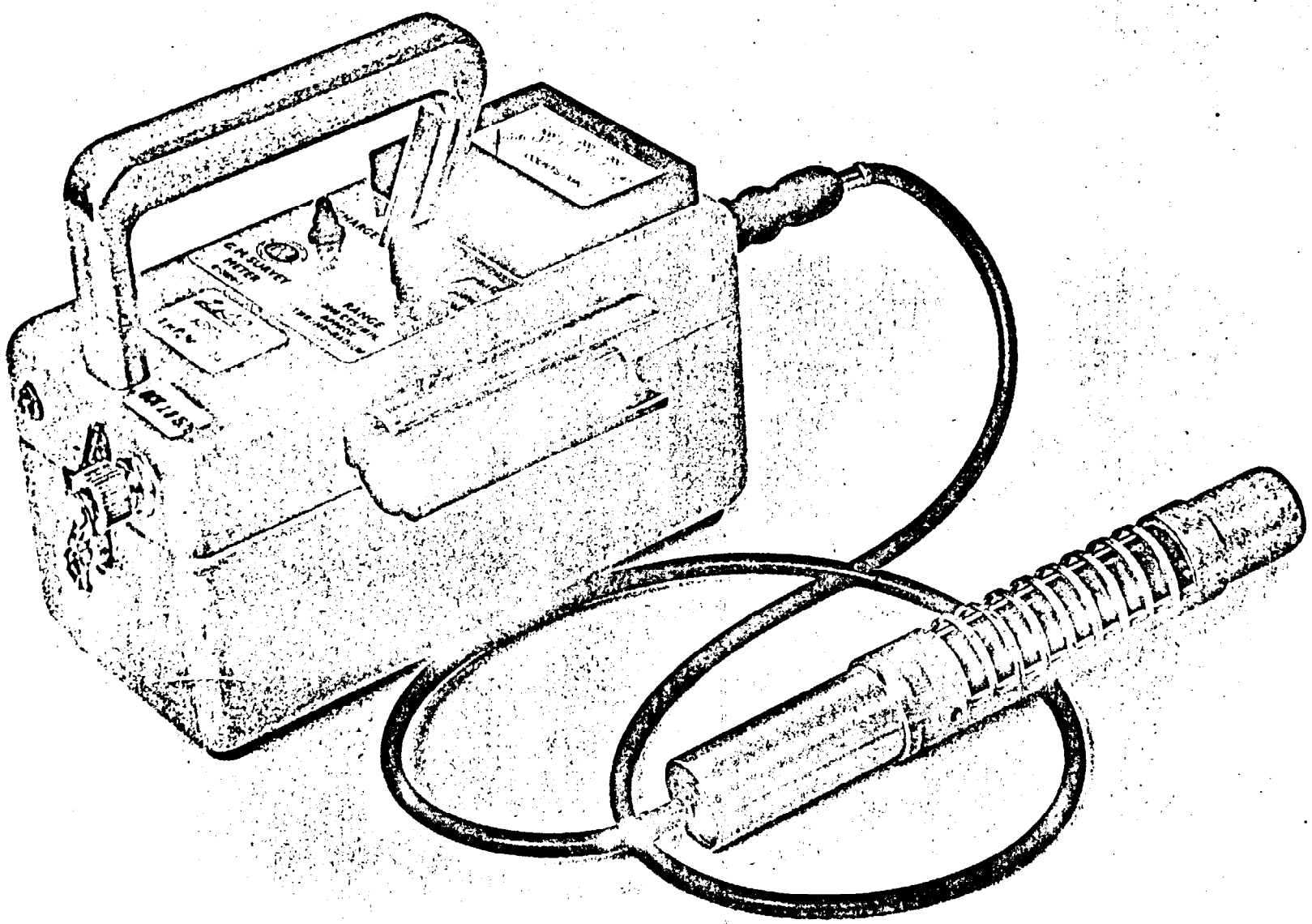


Fig. I-C. Geiger-Muller Survey Meter.

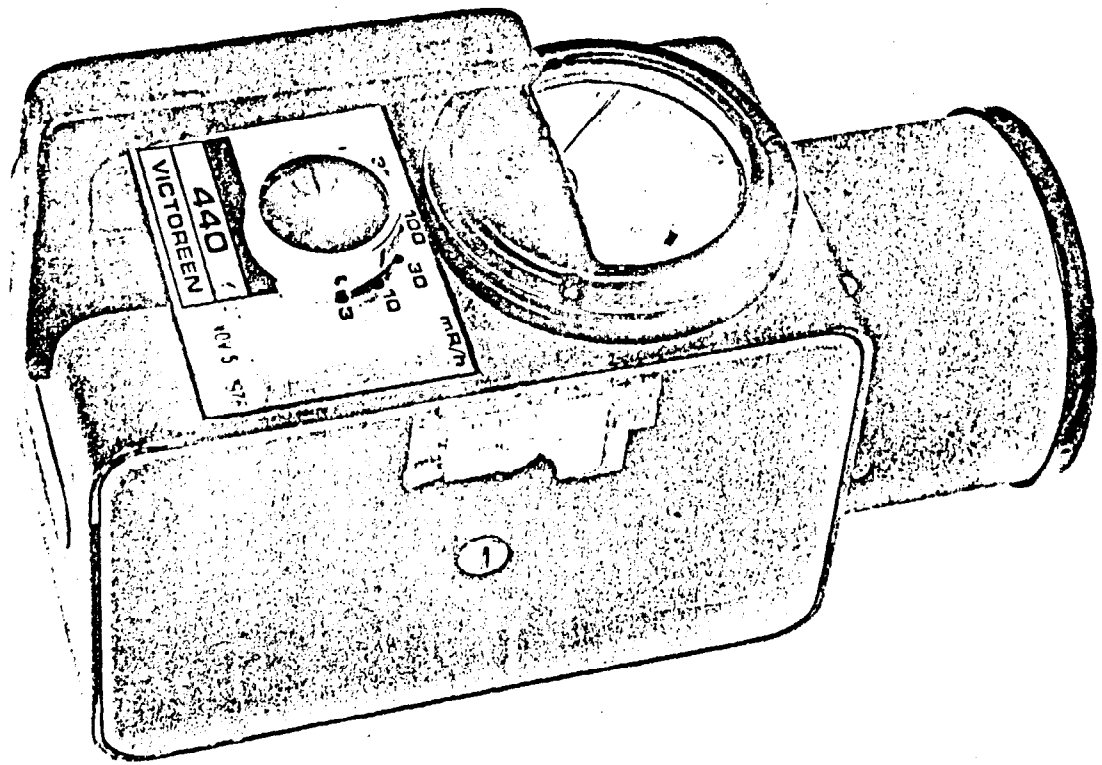


Fig. I-D. Victoreen Model 440 Ionization Chamber.

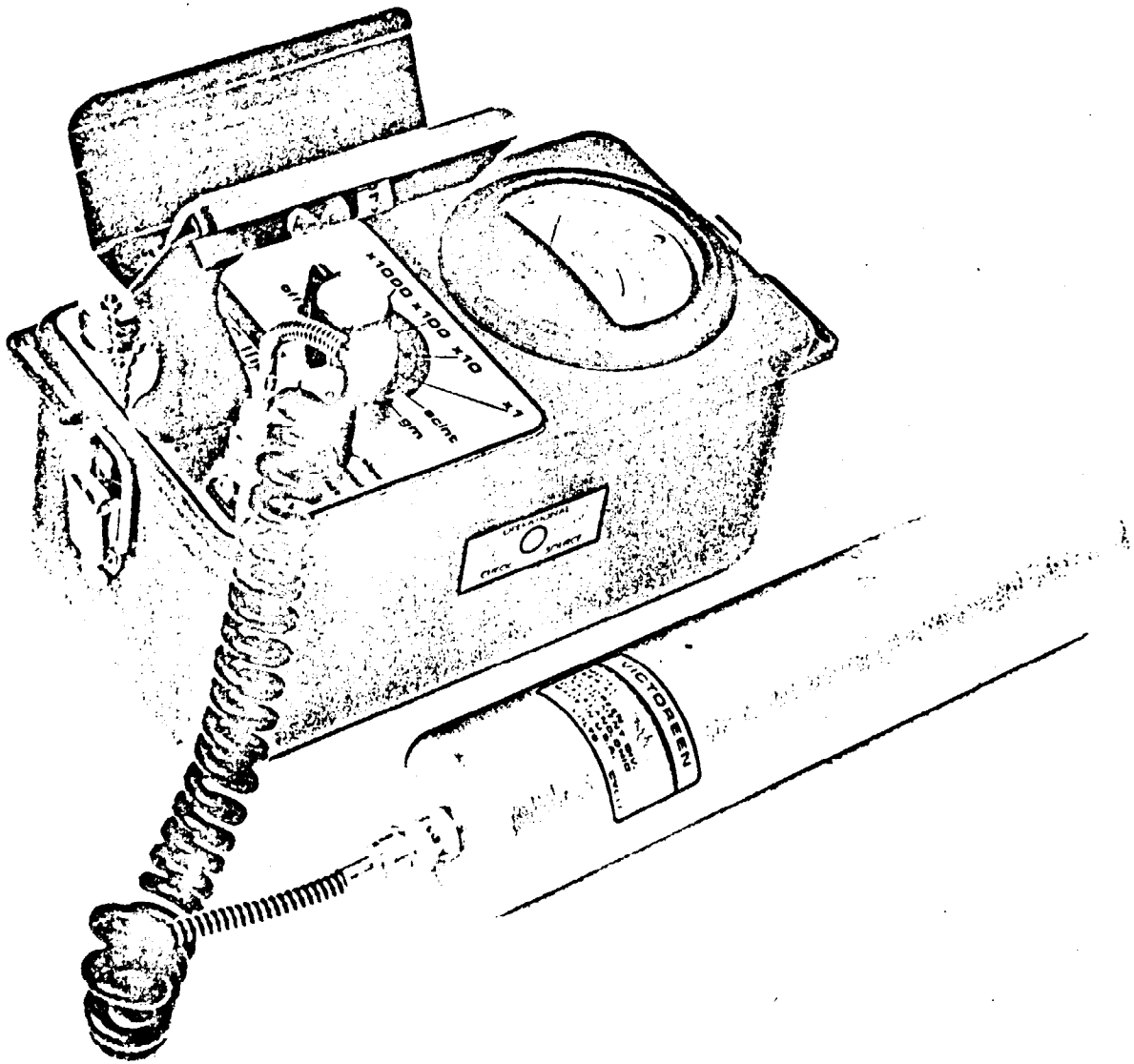


Fig. I-E. Victoreen Model Thyac III Ratemeter.

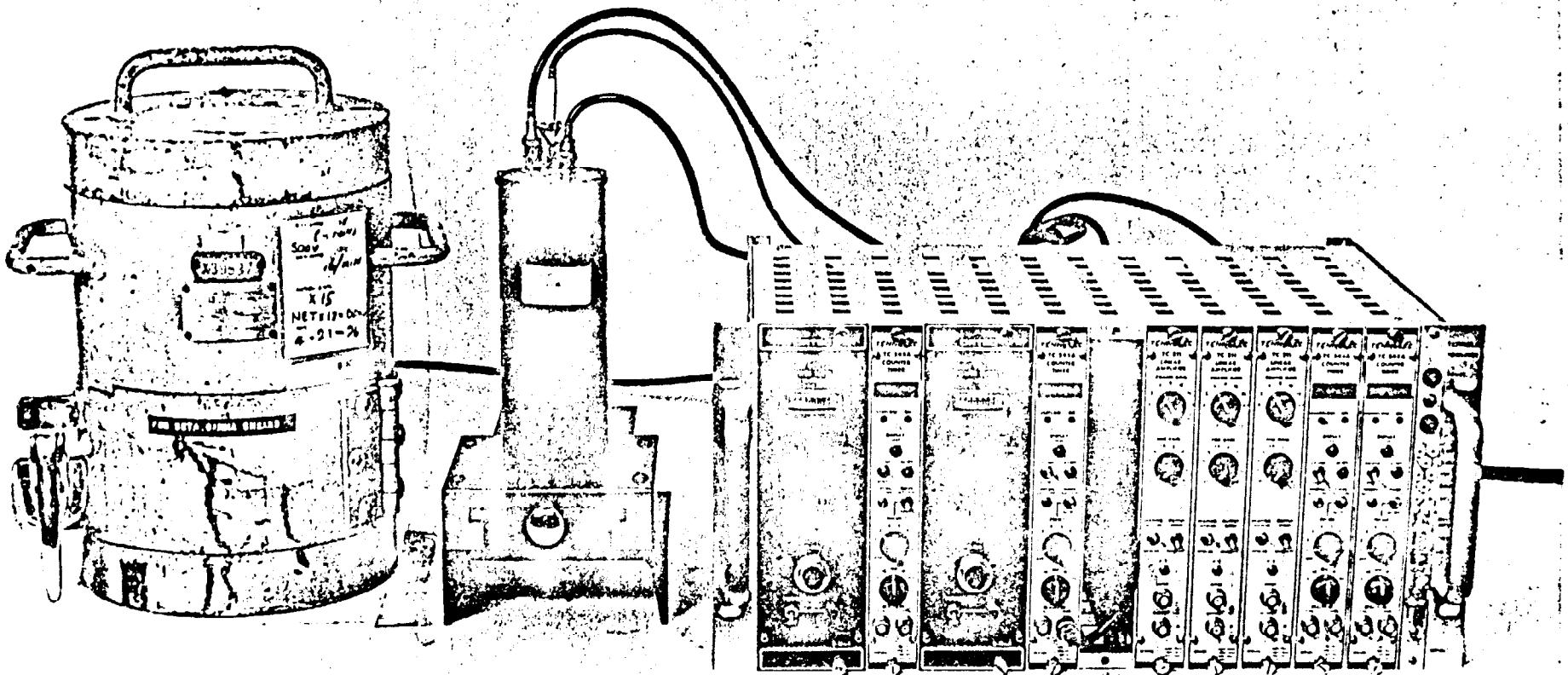


Fig. I-F. Alpha and Beta Smear Counters.

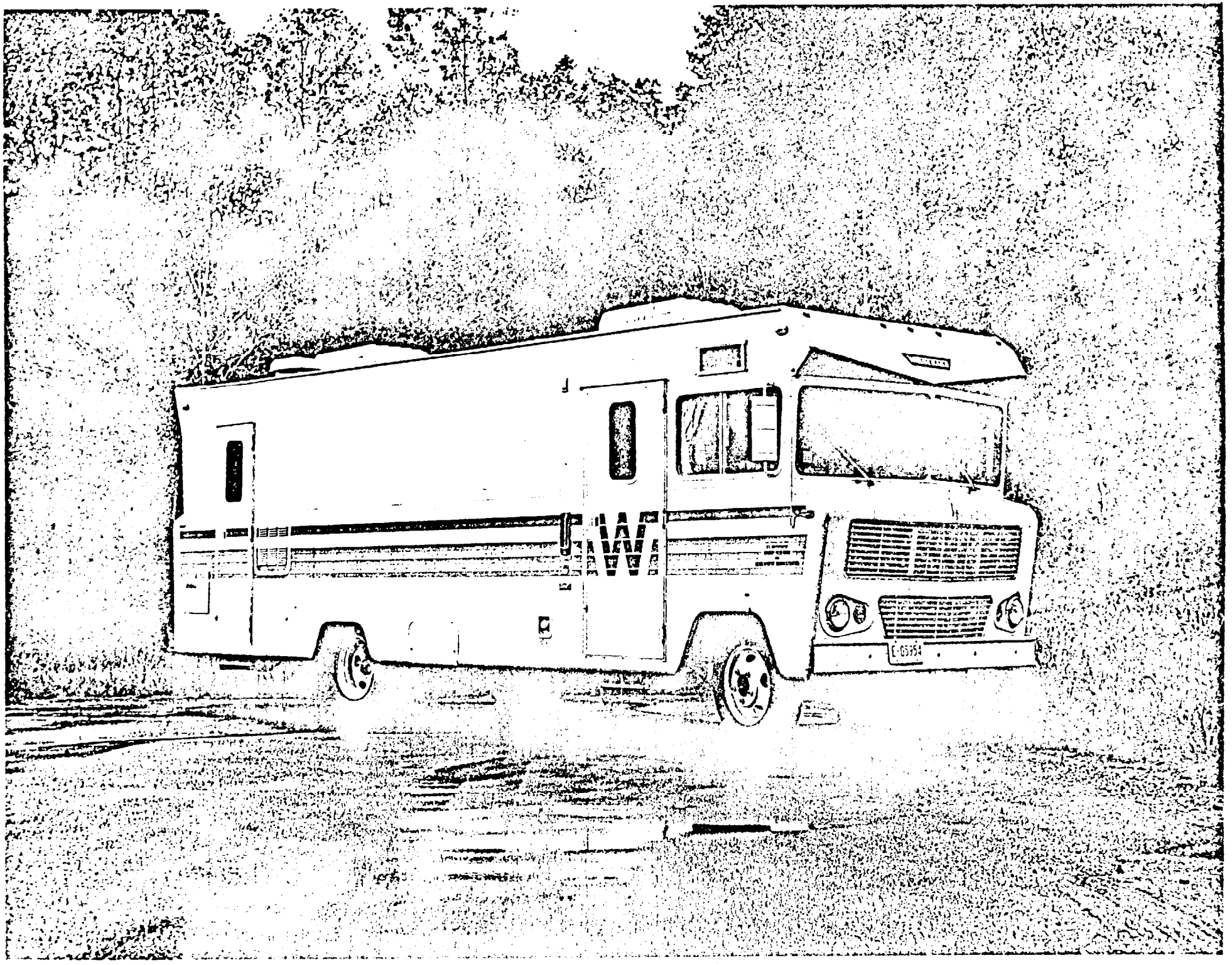


Fig. I-G. Mobile Lab Used on Survey.

APPENDIX II

DESCRIPTION OF THE TECHNIQUES FOR THE MEASUREMENT OF RADON AND RADON DAUGHTER CONCENTRATIONS IN AIR

Technique for the Measurement of ^{222}Rn Progeny Concentrations in Air

An alpha spectrometry technique has been refined by Kerr[1,2] for the measurement of ^{222}Rn progeny concentrations in air. From one integral count of the ^{218}Po alpha activity and two integral counts of the ^{214}Po alpha activity, the concentrations in air of ^{218}Po, ^{214}Bi and ^{214}Pb may be calculated.

Particulate ^{222}Rn daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 5 minutes and a flow rate of 12 LPM are used. This filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for radon daughter measurements are shown in Fig. II-A. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used as a chamber fill gas.[3] In this counter, helium is flowed between the diode and the filter sample, which are separated by a distance of 0.5 cm. One integral count of the ^{218}Po alpha activity is obtained from 2 to 12 minutes, and two integral counts of the ^{214}Po activity are obtained from 2 to 12 minutes and 15 to 30 minutes, respectively. All counting intervals are referenced to t = 0 at the end of sampling.

The equations describing the ^{222}Rn progeny atoms collection rates on the filter are of the form

$$\frac{dn_i(t)}{dt} = C_i v + \lambda_{i-1} n_{i-1}(t) - \lambda_i N_i(t) \qquad (1)$$

where

n_i = number of the i^{th} species of atom on the filter as a function of time

λ_i = radioactive decay constant of the i^{th} species (min^{-1})

C_i = concentration of the i^{th} species (atoms l^{-1})

v = air sampling flow rate (liters min^{-1})

The solution of Eq. (1) is of the form

$$y = e^{-ax} \left[y_0 = \int F(x)\, e^{ax} dx\right]$$

From the general form of the solution, specific equations can be obtained describing the number of each ^{222}Rn decay product collected on the filter as a function of time. Also by letting $v = 0$ in Eq. (1), a set of equations describing the decay on the filter of each ^{222}Rn progeny can be obtained. The equations describing the decay of ^{222}Rn progeny on the filter can be integrated and related to the integral counts obtained experimentally. Values for the total activities of ^{218}Po, ^{214}Pb, and ^{214}Bi on the filter at the end of sampling are obtained by applying matrix techniques. The airborne concentrations are obtained by solving the equations describing the atom collection rates on the filter. A computer program has been written to perform these matrix operations, to calculate the air concentrations of the radon progeny, and to estimate the accuracy of the calculated concentrations.

Technique for the Measurement of Radon Concentrations in the Air

A Lucas Chamber (Fig. II-B) consists of a 95-ml glass flask, coated inside with a uniform layer of zinc sulfide. For measurements of radon concentration in the air, the flask is evacuated to a pressure of 50 microns. The flask is then taken to a location where a sample is desired and the collection valve is opened. After collection of air in the flask,

sample counting is delayed 3 to 4 hours to allow the radon daughters to attain equilibrium. Alpha particles from the radon daughters produce scintillations in the zinc sulfide. The sample is normally counted for 1000 seconds with a photomultiplier tube assembly. A calibration performed at ORNL using a known radon concentration indicated that the conversion factor is 2.02 pCi/l per cpm. After the sample has been counted, the flask is again evacuated to 50 microns to prevent contamination.

References

II-1. G. D. Kerr, Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectrometry, ORNL/TM-4924 (July 1975).

II-2. G. D. Kerr, "Measurement of Radon Progeny Concentrations in Air," Trans. Am. Nuc. Soc. 17, 541 (1973).

II-3. P. T. Perdue, W. H. Shinpaugh, J. H. Thorngate and J. A. Auxier, "A Convenient Counter for Measuring Alpha Activity of Smear and Air Samples," Health Phys. 26, 114 (1974).

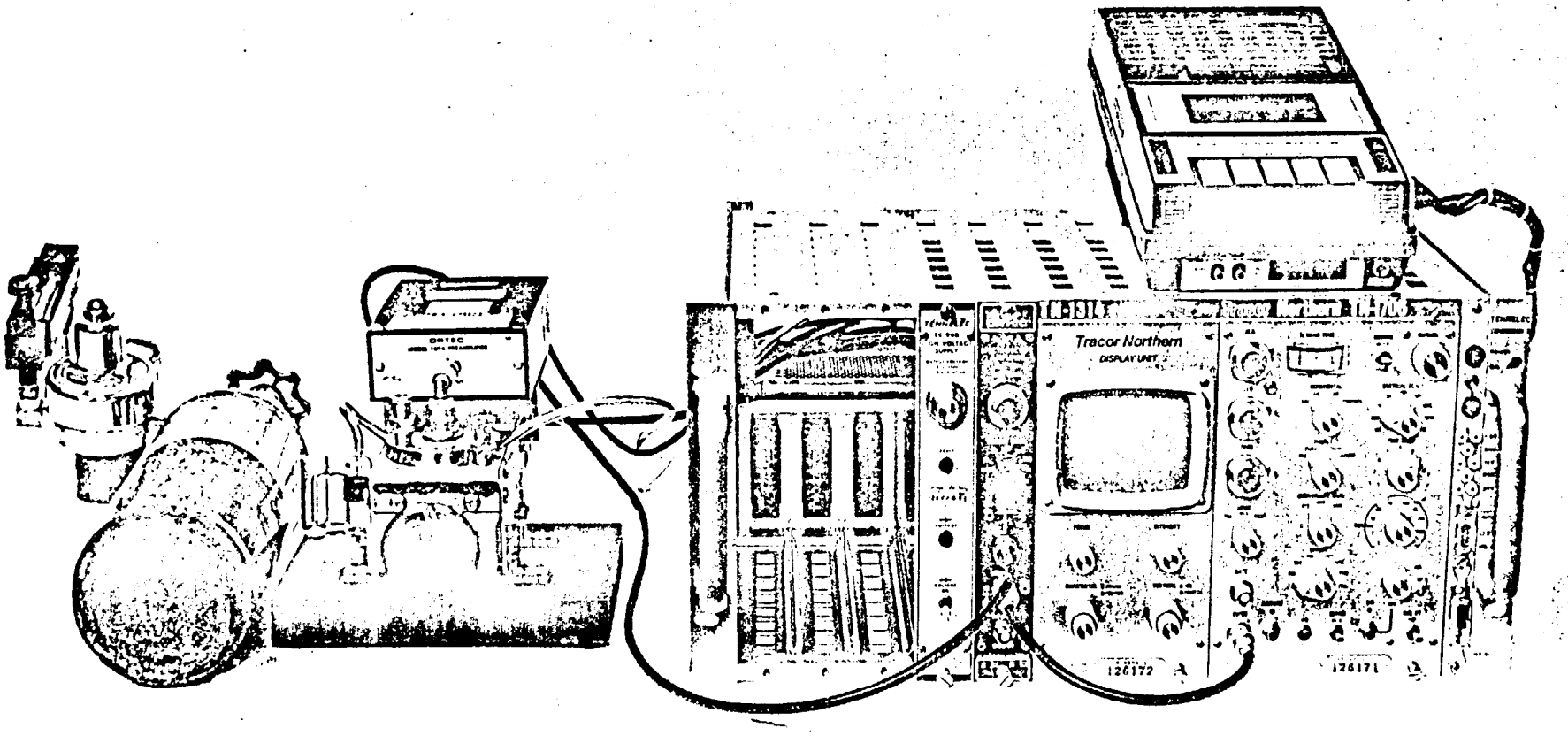


Fig. II-A. System Used for Measurement of Radon Daughter Concentrations.

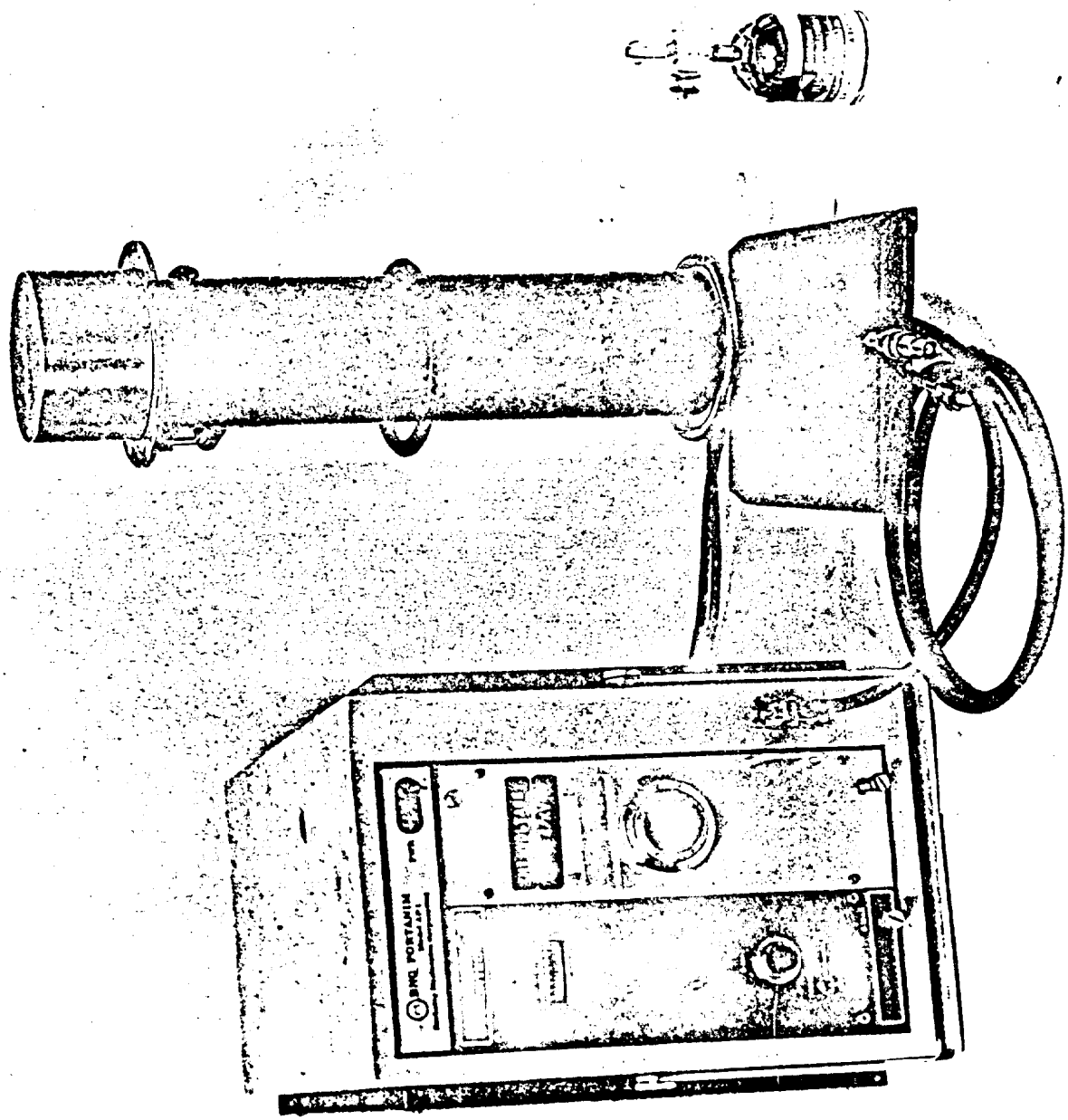


Fig. II-6. Lucas Chamber.

APPENDIX III

DESCRIPTION OF GeLi DETECTOR AND SOIL COUNTING PROCEDURES

DESCRIPTION OF GeLi DETECTOR SYSTEM

A holder for twelve 30-cc polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cc Ge(Li) detector system in laboratory counting of radioactivity in environmental samples (see Figs. III-A, III-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300 cc sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ± 10% or less.

Pulses are sorted by a 4096-channel analyzer (see Fig. III-C), stored on magnetic tape, and subsequently entered into a computer program which uses an iterative least squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program relies on a library of radioisotopes which contains approximately 700 isotopes and 2500 gamma-rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 KeV. An estimate of the concentration of ^{238}U is obtained from an analysis of the 93 KeV line from its daughter ^{234}Th.

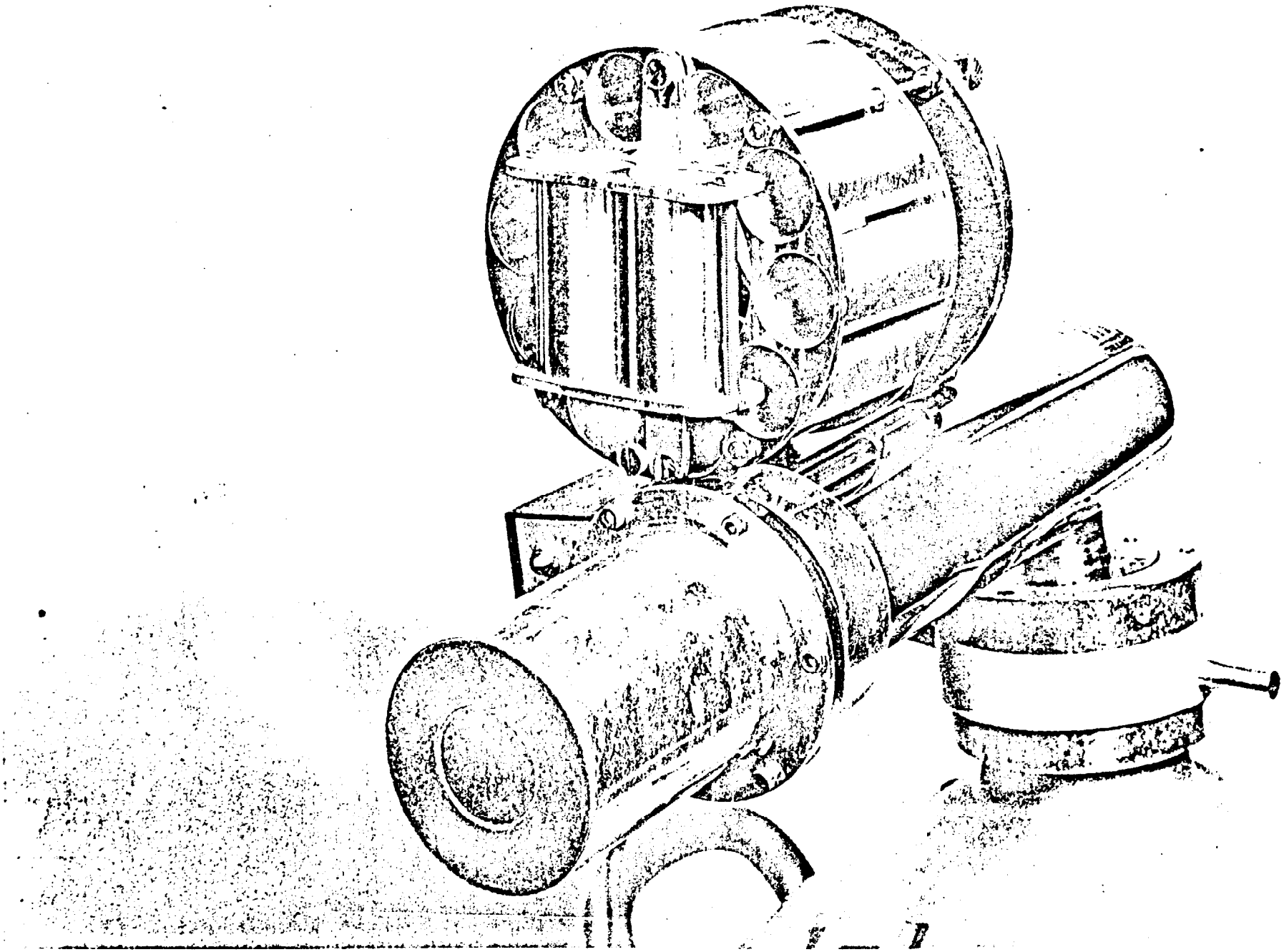


Fig. III-A. Holder for Gell Detector System Samples.

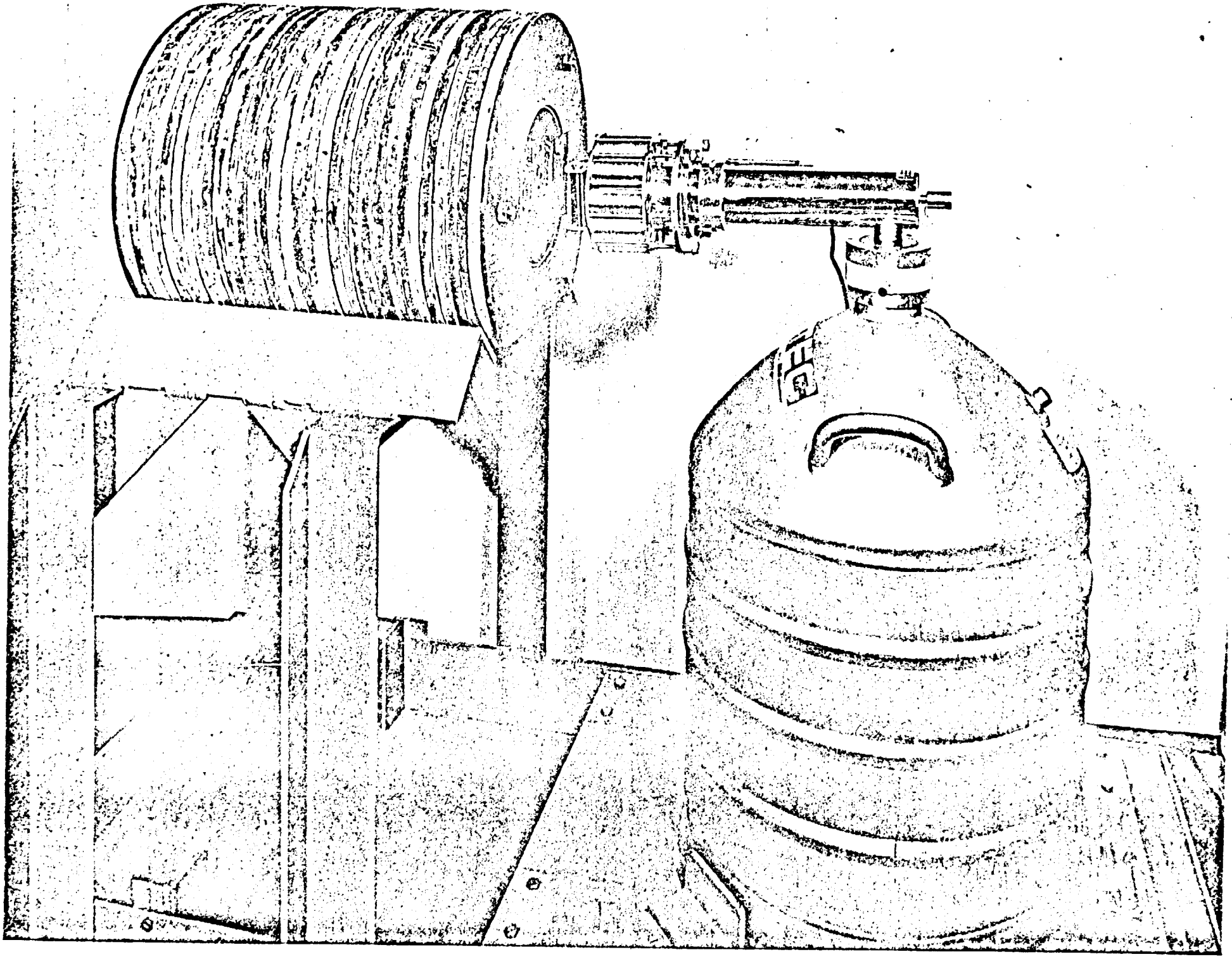


Fig. III-B. Geli Detector System.

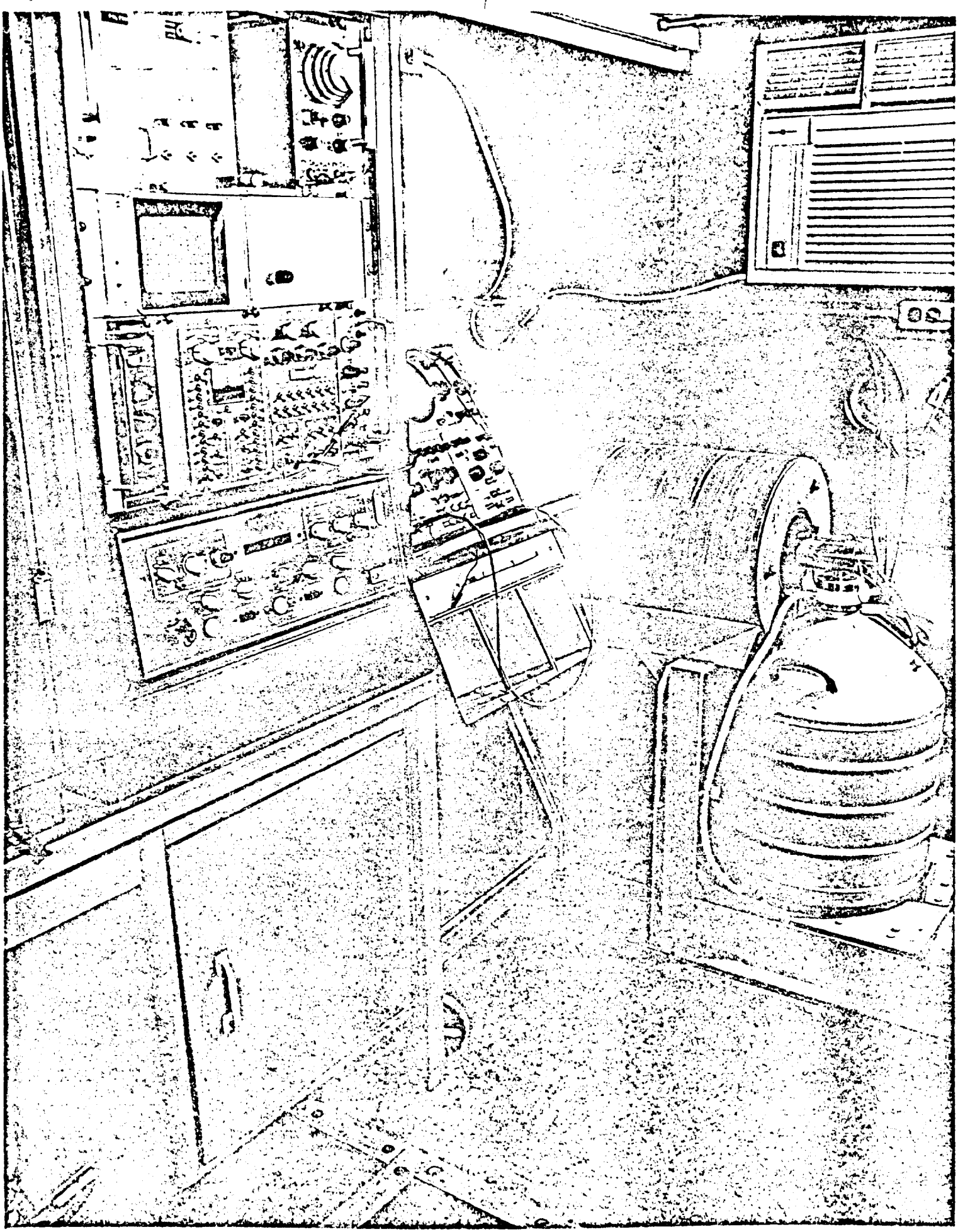


Fig. III-C. 4096-Channel Analyzer.